ACEE Int. J. on Transportation and Urban Development, Vol. 3, No. 1, October 2013

Behavioural Investigation on the use of Nanosilica as An Additive in Concrete

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Abstract - **Influence of Nano science in the Civil Engineering industry outbreaks significant solutions for numerous unidentified blending of materials evolve from a Nano product, which can create gigantic changes in the world of Concrete both technically and economically. The Significance of Nanosilica as an additive in my experimental research congeals the behaviour of Concrete considerably. Essential manipulations are carried out here by using a distinctive methodology and by conducting various tests to innovate a better performance concrete thereby found the enhancement of its property. Nano silica as an additive in added mainly to fill up the deviation arises with the addition of flyash, which consequently deviates the strength after its initial setting period. "Ref. [3]" This presence of Nanosilica constructs the silica (S) in the sand, which ultimately reacts with calcium hydrate (CH) in the cement at Nano scale to form C-S-H bond as its improve the strengthening factor of concrete, which are in turn helpful in the achieving high compressive strength even in early days. Here the addition of Nanosilica are done partially with an previously fly ash replaced concrete in a gradual basis, as the comparative results of a Fly ash concrete and Fly ash with Nanosilica added concrete are tested experimentally. The flexural behaviour of the Nano concrete found to be imperative part as analyzed from the Beam Column joint test setup. It has been clearly concluded in the results identified along with the ductility behaviour and the Load vs. Deflection analysis done for the specimen casted. The standard types of toughness test are carried out, which generated data under specific loading conditions with respect to their component design approaches. Also an overview on the experimental tests conducted in relation with the strength and durability of concrete were presented under the influence of Nanosilica in concrete.**

Keywords - **Nano Silica, Fly ash, Calcium Silica Hydrate, Toughness, Flexure, Nano Concrete**

I. Introduction

Concrete is at something of a crossroads: there are many opportunities and some threats. For those opportunities to change into beneficial practice, engineers, material scientists, architects manufacturers and suppliers must focus on the changes that are required to champion concrete and maintain its dominance within the global construction industry. "Ref. [3]" Recent research has shown that a state-of-the-art process for high-performance cement adds a new dimension to 'classical' cement technology; similarly this is the time to work on "NANO TECHNOLOGY" for development of construction industry by innovations in concrete techniques and also some new materials for the concrete technology. "Ref. [4]" As concrete is most usable material in construction industry it's been requiring to improve its quality. The main objective of this paper is to outline promising research areas.

II. What Is Nano Technology?

"Nanotechnology is defined as fabrication of devices or materials with atomic or molecular scale precision" Nanotechnology is usually associated with study of materials of micro size i.e. one billionth of a meter (a Nanometer) or 10^{-9}m "Ref [9]".

Nano-concrete is defined as "A concrete made with Portland cement particles that are less than 500 Nano-meters as the cementing agent. Currently cement particle sizes ranges from a few Nano-meters to a maximum of about100 micrometers. "Ref. [15]" In the case of micro-cement the average particle size is reduced to 5 micrometers. An order of magnitude reduction is needed to produce Nano-cement. The SEM image of the Nano silica we had taken for our investigation is shown in Fig.1

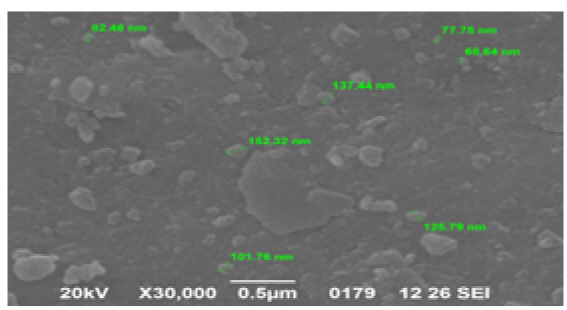

Fig 1: The SEM image of Nano silica

IV. Nanoscale Concrete

- Fundamental research into the interactions between fly ash and the Nanostructure of Portland cement gel is under way, using neutron_scattering technology
- "Ref. [14]" Nanotechnology is providing a close-up

DOI: 01.IJTUD.3.1.1005

ACEE Int. J. on Transportation and Urban Development, Vol. 3, No. 1, October 2013

look at the hydration of cement grains and the Nanostructure of cement reactivity as hydrated surfaces develop on individual cement grains.

- The feasibility of Cyberliths, or Smart Aggregates, as wireless sensors embedded in concrete or soil is under examination.

"Ref. [5]" Concrete ills such as alkali-silica reactivity (ASR) and delayed stringier formation, the bane of concrete highways and bridges, are being explored at the molecular level using neutron-scattering technology and other processes.
and other processes.

V. Objectives Of This Investigation

1. The OPC is partially replaced by fly ash as 20%, 40%, 60%, by weight of blended cement to find the optimum replacement.
2. The blended cement used in this investigation consists of ordinary Portland cement and Nano silica.
3. The Nano silica is added to the concrete as 2.5% of the weight of cement.
4. The strength behavior of beam column joint element after the addition of Nano silica shall observe.
5. Experiments were conducted on beam – column joints under cyclic loading using different fly ash replacement and compared with the conventionally reinforced Nano concrete specimens
6. Studies on Modulus of rupture of concrete were made by partially replacing of cement with fly ash and find out the optimum replacement percentage of fly ash to the weight of cement.
7. To study the index properties of the Nano silica
8. To study the strength properties of concrete replacing cement with fly ash.
9. To study the durability of Nano concrete

VI. Materials And Methods

A. An investigation of Nano silica in cement hydration process

With the advent of Nano technology, materials have been developed that can be applied to high performance concrete mix designs. "Ref. [13]" Nano silica reacts with calcium hydroxide (CH) to develop more of the strength carrying structure of cement: calcium silica hydrate (CSH) "Ref. [8]". In this paper, relationships have been developed to distinguish the benefits when using different sizes of Nano silica in cement paste. An extensive regime of experimental analysis was carried out to determine the effect of Nano silica. Through these experiments the heat of hydration of multiple cement mix designs was measured. After that, the concentration of CH was recorded through X-ray diffraction. "Ref. [4]" Then, the grain structures were examined through Scanning Electron Microscopy. Finally, the compressive strength was determined for each cement paste mixture. Through these experiments it was found that as the silica particles decreased in size and their size distribution broadened, the CSHs became more rigid; this increased the compressive strength."Ref. [7]".

VII. Flexure Test Setup

A. Details Of Specimen

The test specimen was designed to suit the loading arrangement and test facilities. Testing model dimension of beam was 200 X 150 mm without slab thickness and beam length of 750mm and that column size was 150 X 150 mm. Height of the column was 1500mm. The reinforcement details of the specimens are shown in the figure 2.

B. Formwork And Reinforcement

The reinforcement details of beam column joint are shown in figure 2. The main reinforcement provided in the beam was 12 mm diameter bars, 2 Nos. at top and 10 mm diameter bars, 2 Nos. at bottom. The stirrups are 8 mm diameter bars at 150 mm c/c. The longitudinal reinforcement provided in the column was 4 No's of 12 mm diameter bars equally distributed along four sides of column. The column confinements are 8 mm diameter bars at 150 mm c/c. The anchorage bar for seismic detailing is at 600 mm from main reinforcement in beam lapping downwards and 500 mm from the bottom reinforcement in beam lapping upwards.

C. Test Setup And Instrumentation

The experimental setup is arranged as the column was fixed at its ends on a loading frame. It was subjected to a constant axial load of 100 kN which is 50% of ultimate load carrying capacity of the column. This is considered the service load that the column is expected to carry under normal loading conditions. "Ref. [2]" Cyclic load was applied using a hydraulic actuator. The load cycle was predefined as it increased at a uniform rate 0.25mm/cycle.

Each cycle comprises of three full waves of same amplitude in 10s (0.3Hz. frequency). The final tip deflection was 22.5mm. The other end of the beam was free. "Ref. [2]" Vertical deflection of the tip of the beam was recorded directly by the linear variable displacement transducer (LVDT) built in the actuator. It was validated with another external LVDT. The data were collected using a computerized data acquisition system.

D. Load Sequence Diagram

The specimens were tested by applying the cyclic load to get the seismic behaviour of the beam column joint. Magnitude of the load was applied from upward to downward by meeting the load. "Ref. [1]" The manual load was applied using hydraulic jack. The details of the load cycle history are shown in the figure 3:

E. Results And Discussions

For a rectangular sample under a load in a three-point bending setup:

$$\sigma = \frac{3FL}{2bd^2}$$

DOI: 01.IJTUD.3.1.1005

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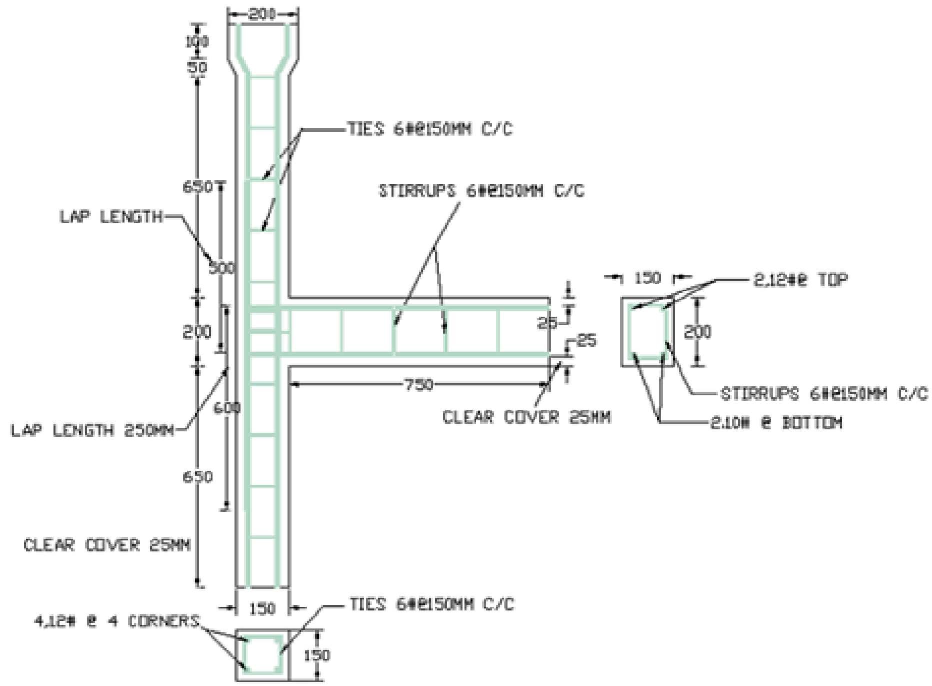

Fig 2: Formwork and reinforcement details

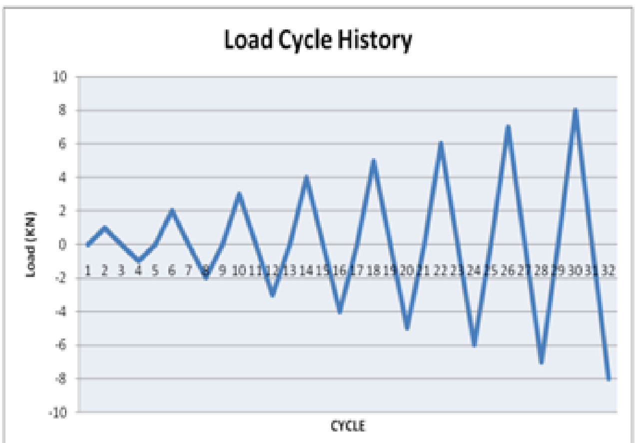

Fig .3 Load Cycle History

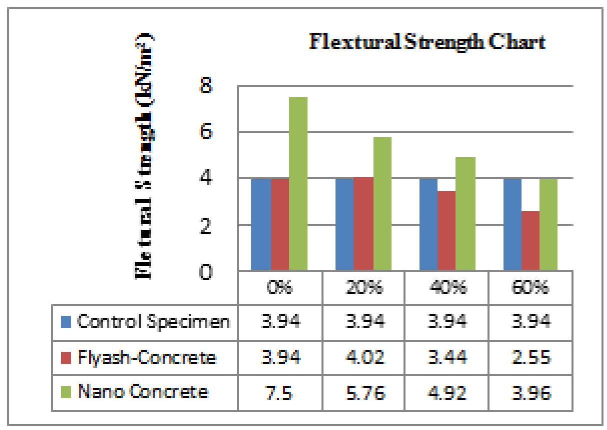

Fig .4 Flexural Strength Chart

- L is the length of the support span
- b is width
- d is thickness
- F is the load (force) at the fracture point

The Flexural Strength chart for the tested specimen are Shown in Fig. 4 and their results are shown in Table I.

Table I: Flexural Strength Details

Specimen	Average load in (kN)	Flexural Strength σ = 3FL/BD 2 (kN/m2)
CS	17.74	3.94
F_{20}	18.09	4.02
F_{40}	15.48	3.44
F_{60}	11.48	2.55
NC	33.81	7.5
FN_{20}	22.14	5.76
FN_{40}	20.68	4.92
FN_{60}	17.82	3.96

Maximum End Defelection

Table II: Maximum End Deflection

Specimen description	Max Lateral load Sustained in (kN)	Column Axial load in (kN)	Number of Cycles	Max. tip deflection of beam in (mm)
CS	15	60	15	4.51
F_{20}	18	60	18	14.62
F_{40}	12	60	12	10.18
F_{60}	8	60	8	8.99
NC	35	60	35	43.85
FN_{20}	27	60	27	37.54
FN_{40}	21	60	21	18.81
FN_{60}	19	60	19	10.44

Load Deflection Curves

The area enclosed in the load–displacement hysteresis loops, can find an estimate of the hysteretic damping. "Ref.

DOI: 01.IJTUD.3.1.1005

[2]" Hysteretic loops were quite wide in both cases, showing high energy dissipation capacity, coherently with the ductile mechanism of failure visually observed. The maximum end deflection for the tested specimen are tabulated and shown in Table: II.

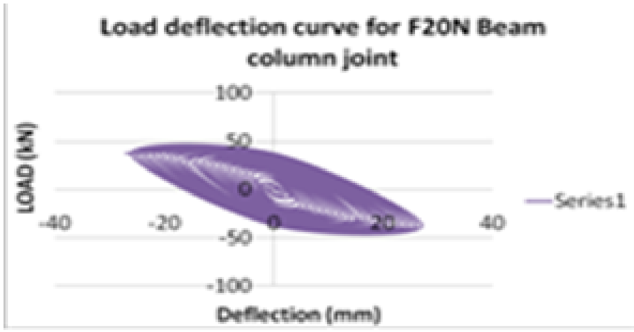

Fig.5 Load deflection curve for F20N specimen

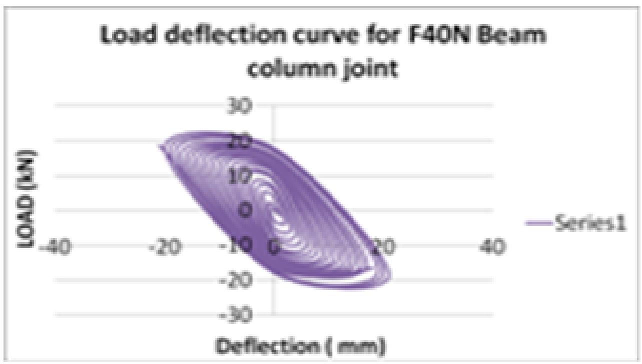

Fig.6 Load deflection curve for F40N specimen

Above shown figure s 5 and 6 displays a comparison of results of a Fly ash added and Fly ash based Nano concrete results. As per our investigation, the beam–column joint prepared with F20N and F40N concrete showed a very stable behaviour up to large number of cycles and the loss in strength was very little cycle by cycle. As we analysed the following points were identified:

a. The failure was in the column portion of the joint for the control specimen, which is to be avoided. Therefore, for the same seismic load, the tensile force in steel is lower in the Nano silica specimen than in the fly ash specimens.

b. Considerable increase in yield load can be achieved by use of these materials.

VIII. Fracture Toughness Testing

A material may be strong and tough if it rupture under high forces, exhibiting high strains, while brittle materials may be strong but with limited strain values so that they are not tough.

"Ref. [7]" Generally speaking, strength indicates how much force the material can support, while toughness indicates how much energy a material can absorb before rupturing.

A. Experimental Procedure:

This experimental program consists of casting of prisms of standard size of 500 mm x 100 mm x 100 mm are tested. The number of prism casted, their id,descriptions and their curing period are separated with Fly ash Concrete prism and 2.5% Nano silica added Concrete prisms.

"Ref. [5]" Under Fracture Toughness testing a single edge notch-bending specimen (also called three point bending specimen) is used.

In this three-point bend test, a fatigue crack is created at the tip of the notch by cyclic loading. The length of the crack is measured. The specimen is then loaded monotonically. "Ref. [6]" A plot of the load versus the crack opening displacement is used to determine the load at which the crack starts growing. This load is substituted into the below formula to find the fracture toughness. K_{Ic}

$$K_1 = \frac{4P}{B}\sqrt{\frac{\pi}{W}}\left[1.6\left(\frac{a}{W}\right)^{1/2} - 2.6\left(\frac{a}{W}\right)^{3/2} + 12.3\left(\frac{a}{W}\right)^{5/2} - 21.2\left(\frac{a}{W}\right)^{7/2} + 21.8\left(\frac{a}{W}\right)^{9/2}\right]$$

Where, "P" is the applied load,
"B" is the thickness of the specimen,
"á" is the crack length, and
"W" is the width of the specimen.

Table: 3 shows the loads induced on the specimen to determine their stress intensity factor:

Table III: Stress Intensity factor for 14 Days Specimen

Specimen	Load (p) N	Crack Length mm	Stress intensity factor K1
C-14	4250	70	95.031
F20-14	3000	50	31.395
F40-14	2250	60	37.263
F60-14	2200	50	23.023
CN-14	4500	60	67.073
FN20-14	3500	70	78.2261
FN40-14	2500	70	55.901
FN60-14	2500	50	26.163

B. Test Setup And Analysis Of Result

The test specimens stored in water at a temperature of 24° to 30°C for 48 hours before testing shall be tested immediately on removal from the water whilst they are still in a wet condition. The dimensions of each specimen shall be noted before testing. No preparation of the surfaces is required.

Results for 28 days results of Stress intensity factor of a Fly ash concrete and Nano added Fly ash concrete are shown in Table: IV.

C. Stress Strain Curve Results:

Under varying loading condition the specimens are tested under Control Mix, Partial replacement of cement with fly ash of 20%, 40% and 60% and Nanosilica added concrete, the stress strain values are charted below in a graphical analysis and the results for 20% and 40% replacement were shown below in Fig: 7,8,9,10 and 11.

DOI: 01.IJTUD.3.1.1005

TABLE IV: STRESS INTENSITY FACTOR FOR 28 DAYS SPECIMEN AS PER ASTM STANDARDS

Sl. No	Weight of replacement of fly ash (%)	Size of Prism (mm)	Stress Intensity factor K1	Stress Intensity factor K1
1	0	500x100x100	40.296	55.559
2.	20	500x100x100	37.202	34.012
3.	40	500x100x100	37.263	28.779
4.	60	500x100x100	17.059	16.934

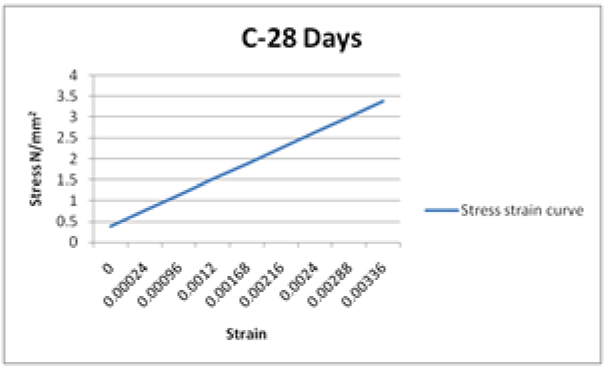

Fig. 7. Shows the stress strain curve for C-28 days

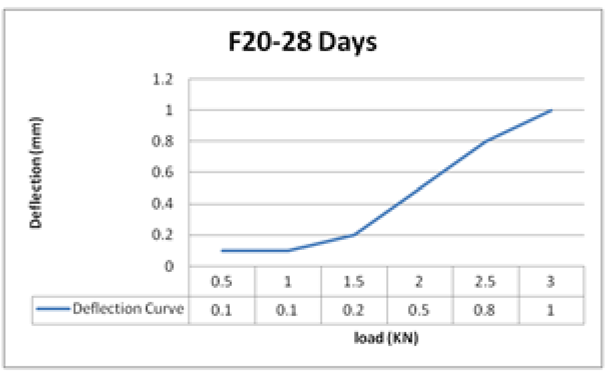

Fig. 8. Shows the stress strain curve for F20 - 28 days

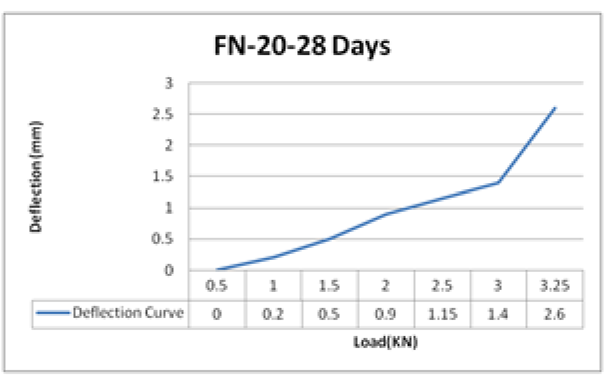

Fig. 9. Shows the stress strain curve for F20N - 28 days

The below graphs shows the results of Fly ash concrete and Nano additive in Fly ash concrete and their Stress Strain variations for 28 days.

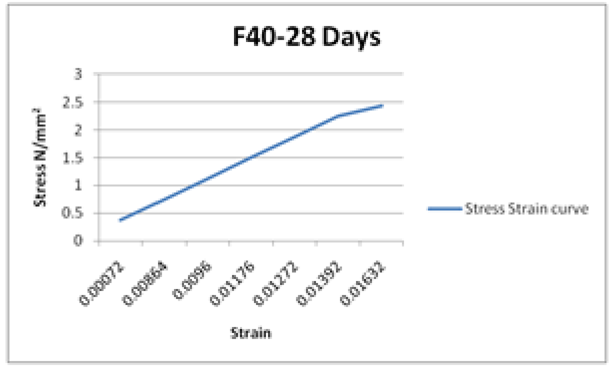

Fig. 10. Shows the stress strain curve for F40-28 days

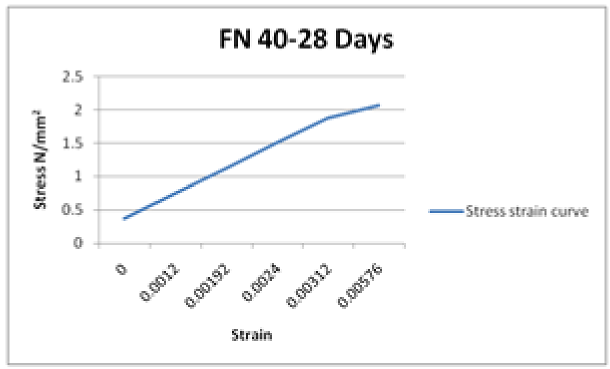

Fig. 11. Shows the stress strain curve for F40N-28 days

D. Discussions

1. The Flexural modulus of concrete increases in addition of Nano silica is higher than the concrete casted with OPC and concrete casted only with addition of fly ash.
2. "Ref. [5]" The flexural modulus value increases simultaneously the toughness value of the material get increases.
3. The toughness value of the Nano concrete shows better result than ordinary concrete.
4. The FN20 and FN40 concrete specimen have higher stiffness when compare to all other concrete specimen.
5. The toughness index value is comparatively toughened in FN20, FN40 than F20, F40 respectively.

IX. IMPACT TOUGHNESS TEST

This test is widely used because of its simplicity and economy. Thus, several impact test methods have been used to demonstrate the relative brittleness and impact resistance of concrete. However, none of these test methods have been standardized yet.

A. Experimentation Setup: Drop weight method of impact test

The size of the specimen recommended by the above committee is 150 mm in diameter and 64 mm in height. The equipment consists of a standard manually operated 10 lb (45 N) compaction hammer with an 18 inch drop (457 mm) (ASTM D 1557-70), a 64 mm diameter hardened steel ball and

DOI: 01.IJTUD.3.1.1005

a flat base plate with positioning bracket. In addition to the above equipment, a mould to cast 150 mm diameter and 64 mm thick concrete specimen is needed. The thickness of the specimen is recorded to the nearest millimeter as its center and at the ends of a diameter prior to the test "Ref[10]".

B. Specimen Details

Eight specimens of sizes 150 × 64-mm are casted as shown in the below Fig.12. They were then struck with repeated blows by Drop weight method. The blows were introduced through a 4.45 kg hammer dropping frequently from a 45.7-cm height the specimens and impact base plate and the test procedure. "Ref. [11]" The numbers of blows producing the first visible crack and cause ultimate failure were recorded. In each test, the number of blows to produce the initial visible crack was recorded as the first crack strength, and the number of blows to cause complete failure of the disc was recorded as the failure strength.

"Ref [12]" The Impact resistance of the specimens was determined as well in accordance with the ACI committee 544 and results are shown in Table: 5.

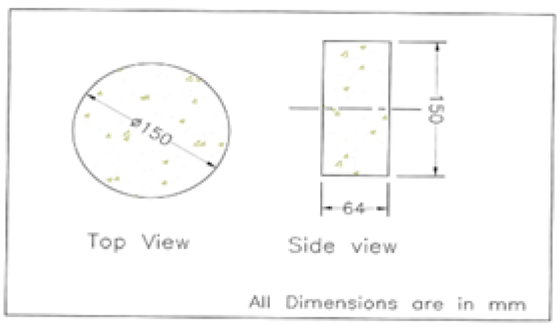

Fig. 12. Shows the Dimension of the Disc Specimen

C. Test Results

Table V: Test results for Impact resistance of Nano added Fly ash concrete

Mix no.	Impact resistance (blows)		Impact energy (kN mm)		PINPB (blows)
	First crack (N1)	Failure (N2)	First crack	Failure	
C	12	16	244.128	325.504	33.33
F20	8	11	162.752	223.784	37.50
F40	4	7	61.032	101.72	75.00
F60	3	5	40.688	101.72	66.67
CN	15	27	305.16	549.288	80.00
FN20	11	18	183.096	223.784	63.64
FN40	7	11	142.408	183.096	57.14
FN60	5	7	81.376	142.408	75.00

Where,
PINPB - Percentage increase in number of post-first-crack blows to failure.

D. Discussions

- A similar trend to that specified for N1 is observed for N2 values. On the other hand, PINPB values that indicate the ability to absorb kinetic energy suggest that adding Nano silica delays failure strength.
- The PINPB Values of the Nano concrete in 2.5 times greater than Control concrete specimen.
- On Addition of fly ash, despite increasing the strength it leads to higher brittleness.
- "Ref. [7]" It can be concluded that, by adding Nano silica, the failure crack pattern changed from a single large crack to a group narrow cracks, which demonstrates the beneficial effects of Nano concrete subjected to impact loading.
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X. Conclusions

From the above experiments and results we conclude that:

- Nano-silica consumes calcium hydroxide crystals, reduces the size of the crystals at the interface zone and transmute the calcium hydroxide feeble crystals to the C-S-H crystals, and improves the interface zone and cement paste structures.
- Deflection of the concrete decreases with adding the Nano-silica, especially at early ages. However the early strength of the concrete decreases slightly with adding the fly ash, but decreases at later ages. These results indicate that the Nano silica may adopt for higher strength green concrete technologies.
- Workability of concrete gets increased with the addition if Nano silica
- Avoiding dumping of fly ash in open land or pond controls pollution.
- Effective waste management has been done since the use of fly ash is a recent finding, which was before a waste from thermal stations dumped into land or water resources.
- Economical concrete achieved because fly ash is a waste, which can be procured for low cost compared to cement.
- Corrosion resistance of the concrete is increased with the addition of Nano silica.
- Permeability of concrete is reduced since Nano silica fills even the small voids in concrete.
- The peak results of the stress intensity factor can be achieved through the Nano concrete.
- It can be concluded that by adding Nano Silica the failure crack pattern changed from a single large crack to a small cracks, which demonstrates the beneficial effects of the Nano fly ash used concrete subjected to Impact loading.
- From the above conclusion and graphical approach shows Nano added Fly ash concrete absorbs much more energy than normal fly ash used concrete.

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DOI: 01.IJTUD.3.1.1005